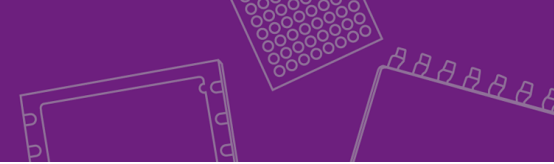




SpanSion Sensor-less Inverter Fan Motor Solution

Oct. 2014 Devin Zhang



a

Background Introduction

b

Algorithm and Function

c

Solution Performance Feature

d

Spancion Solution Development

e

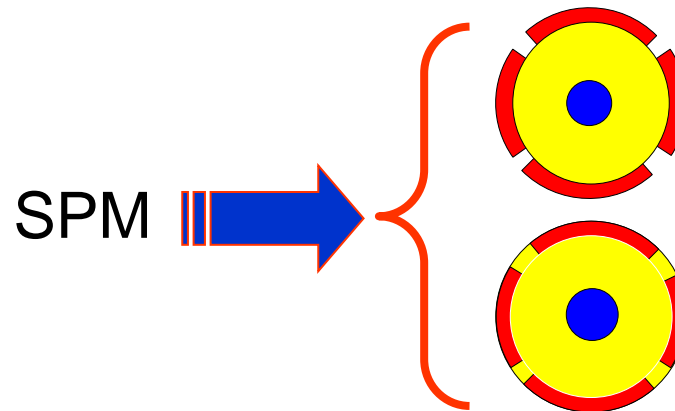
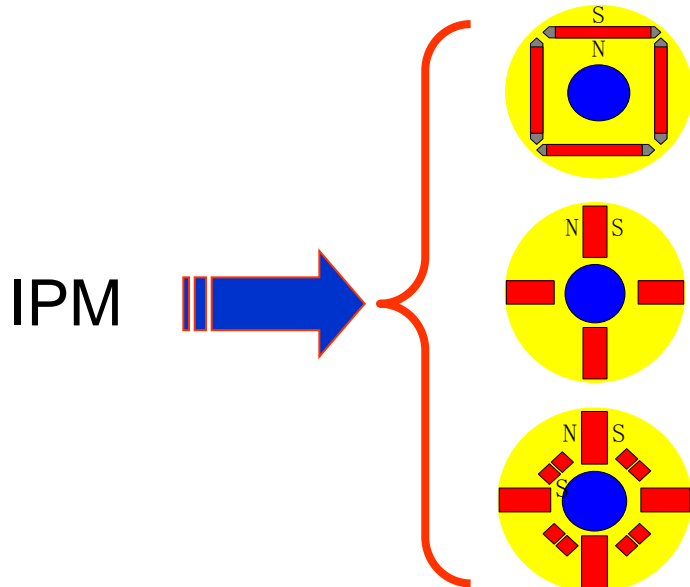
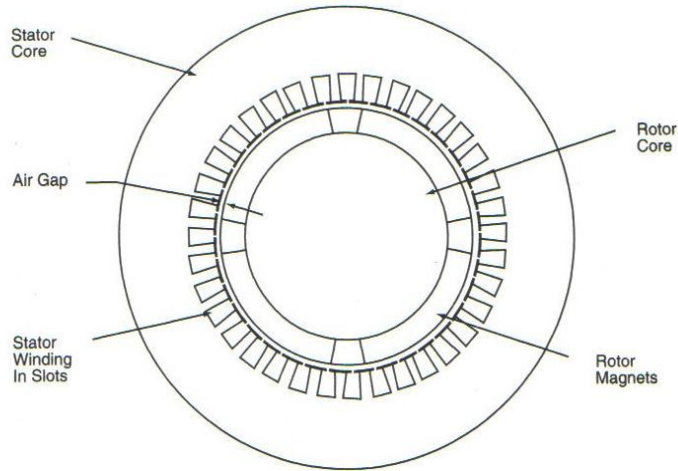
Supported Products



Background Introduction

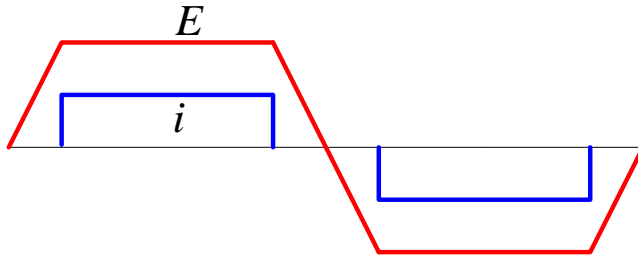
Background Introduction

Motor structure

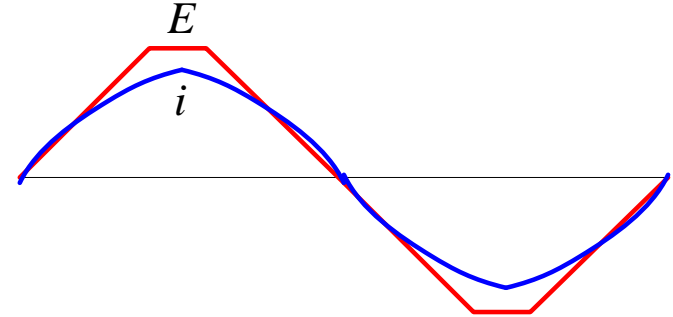


Background Introduction

Motor control algorithm



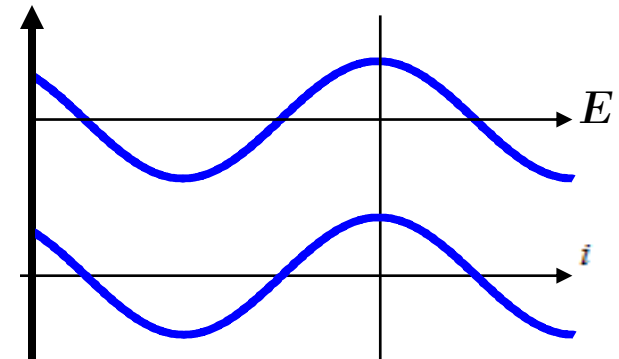
Traditional six step control
(120°)



Traditional FOC control
(180°)

Improvement:

- The BEMF converts into the form of a sine wave—fit 180° control
- The distribution of winding
- Adjust the air gap
- Change the shape of the permanent magnet



Improve motor structure and control algorithm
(180°)

Background Introduction

❑ Control Solution Improvement

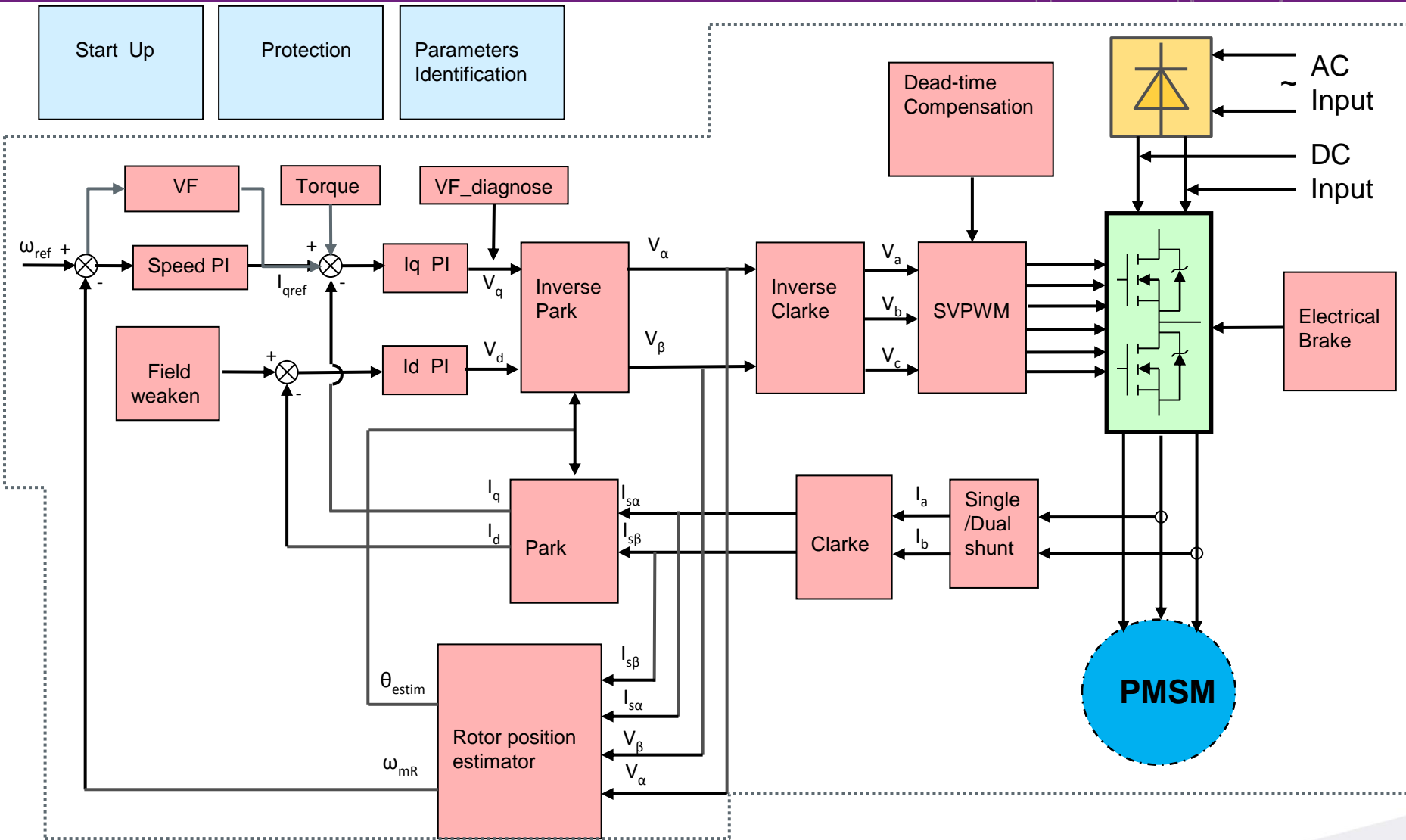
- ★ AC motor efficiency is low and the speed range is narrow.
- ★★ For sensor motor, the price is higher and the Hall is easily mangled.
- ★★★ Existing DC fan solution needs orientation in startup; open-loop startup causes more power loss; performance of anti-wind startup is not good enough.
- ★★★★★ The Spansion sensor-less DC fan solution solves the above problems by providing the following functions: realizing no-orientation and no-vibration startup; providing higher efficiency and wider speed range; realizing perfect anti-wind startup; and reducing hardware price and noise.

Perfect performance !



Algorithm and Function

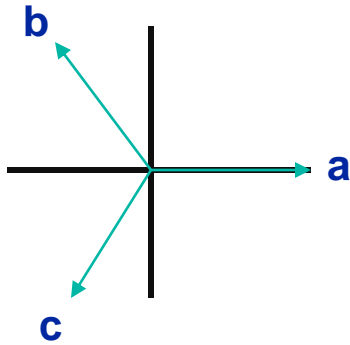
Algorithm Structure



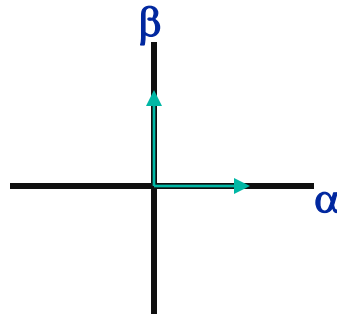
Algorithm Function

- ☐ 1 Catch- Spin function
- ☐ 2 ELE-brake function
- ☐ 3 ELE-brake current control function
- ☐ 4 Anti-wind startup function
- ☐ 5 Rotor direction detect function
- ☐ 6 Self-adapt startup function
- ☐ 7 VF/VF_diagnosis function
- ☐ 8 Torque control function
- ☐ 9 On-line carrier frequency vary
- ☐ 10 Unstop running
- ☐ 11 Dead Time Compensation
- ☐ 12 Field weaken function
- ☐ 13 GUI debugger function
- ☐ 14 Parameters Identification
- ☐ 15 Pulse speed feedback function
- ☐ 16 Vsp speed control function
- ☐ 17 NTC/PTC speed limit function
- ☐ 18 Single shunt function
- ☐ 19 Inner CR choose function
- ☐ 20 Full-scale protected function
 - rotor lock protection
 - loss phase protection
 - soft over-current protection
 - over and under voltage protection
 - loss flux protection

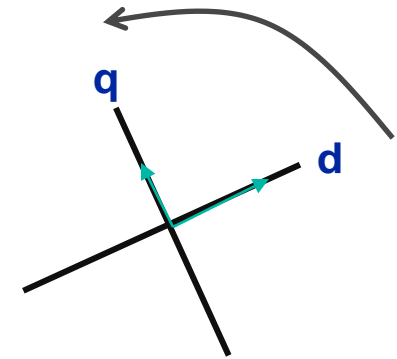
Coordinate Transformation--- Coordinate System



Three-axis stator coordinate system

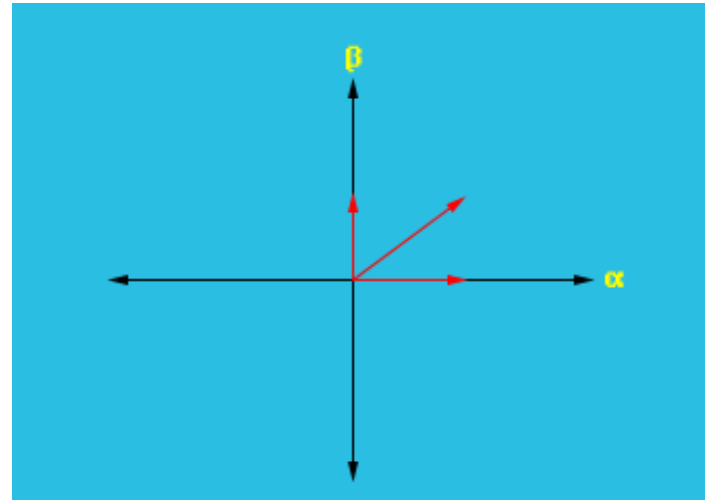
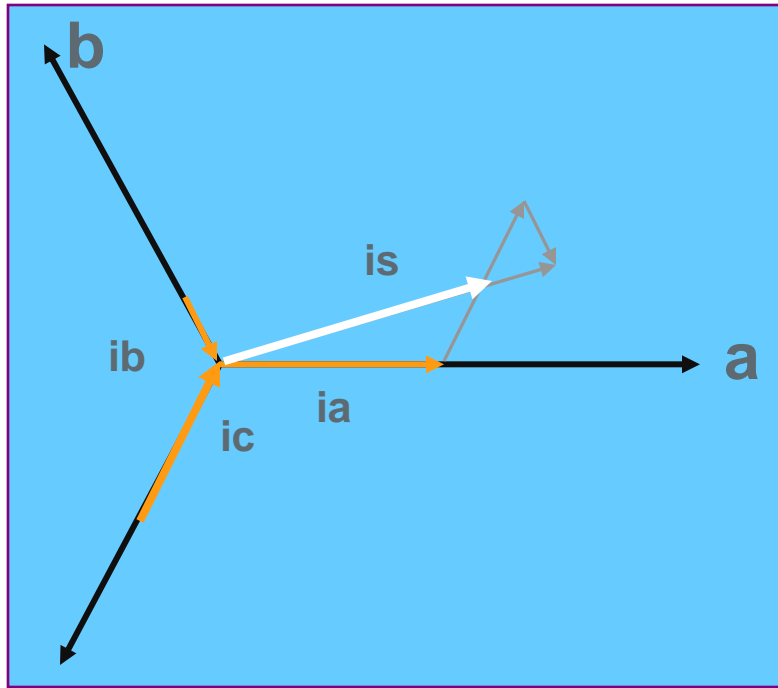


Two-axis stator coordinate system



Two-axis rotate coordinate system

Coordinate Transformation --- Clarke Transform



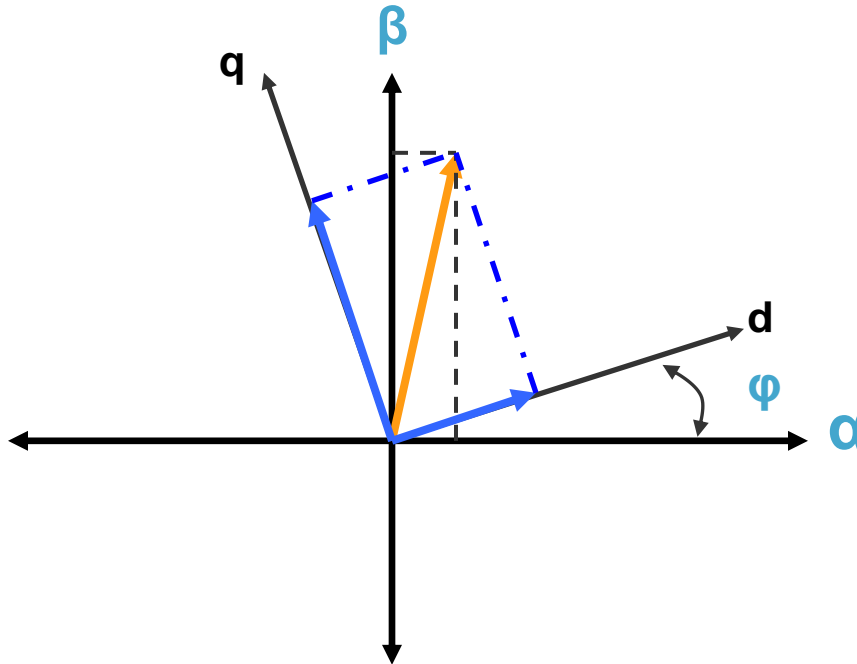
$$\bar{a} = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$$

$$\bar{a}^2 = -\frac{1}{2} - j\frac{\sqrt{3}}{2}$$

$$\vec{x} = x_a + jx_\beta = \frac{2}{3}(x_a + \bar{a}x_b + \bar{a}^2x_c)$$

$$\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \cdot \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix}$$

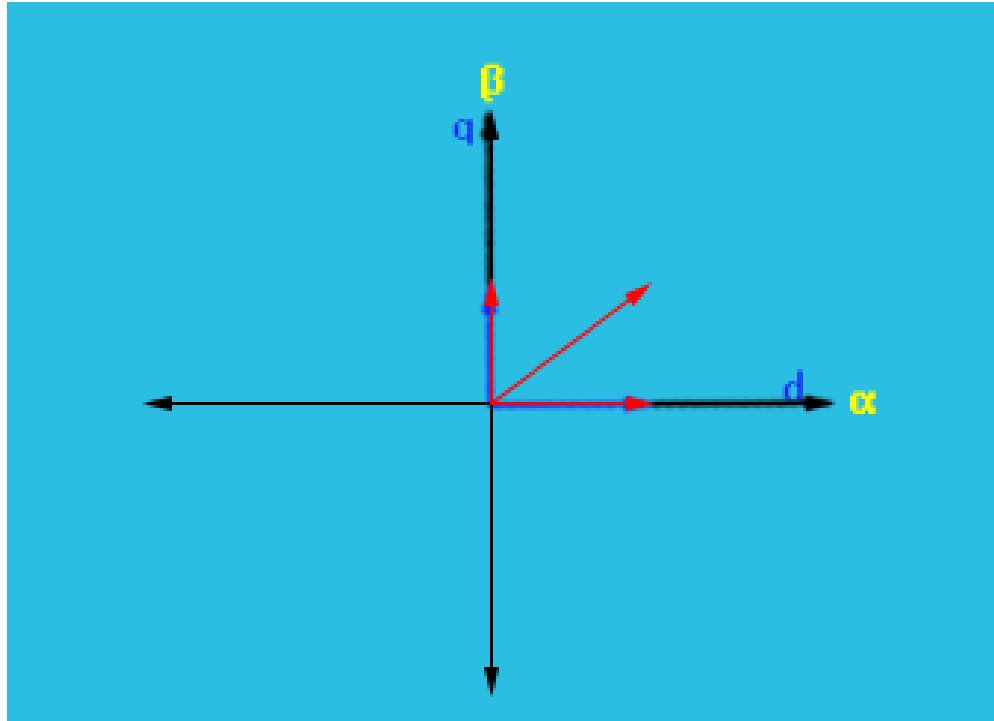
□ Coordinate Transformation ---Park Transform



$$x_d = x_\alpha \cos \varphi + jx_\beta \sin \varphi$$

$$x_q = -x_\alpha \sin \varphi + jx_\beta \cos \varphi$$

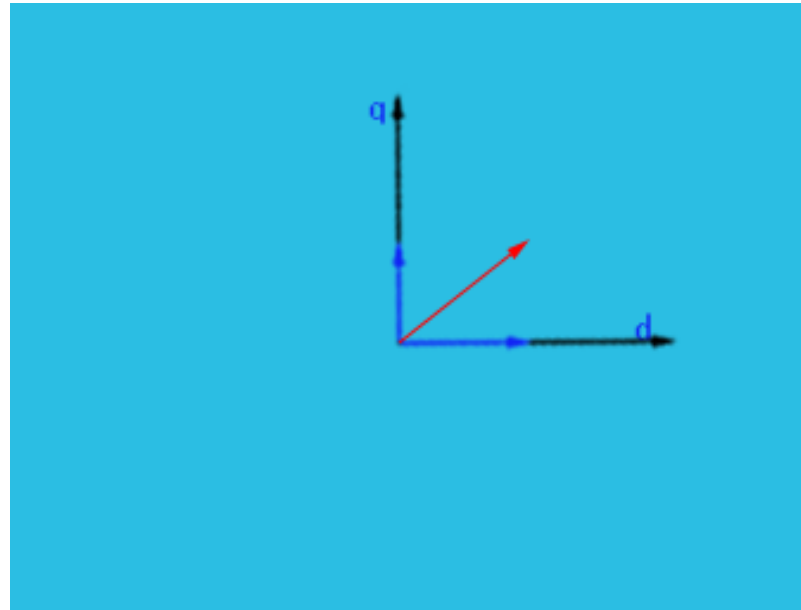
□ Coordinate Transformation --- Inverse Park Transform



$$x_{\alpha} = x_d \cos \varphi - x_q \sin \varphi$$

$$x_{\beta} = x_d \sin \varphi + x_q \cos \varphi$$

□ Coordinate Transformation --- Inverse Clarke Transform

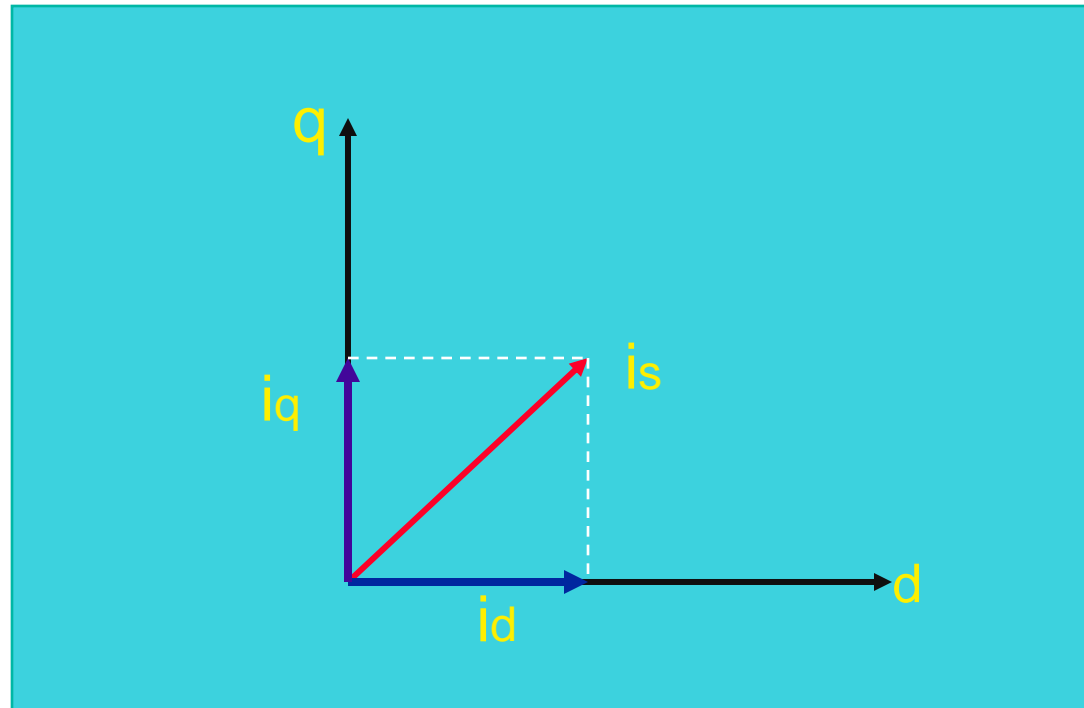


$$x_1 = x_\alpha$$

$$x_2 = \frac{-x_\alpha + \sqrt{3}x_\beta}{2}$$

$$x_3 = \frac{-x_\alpha - \sqrt{3}x_\beta}{2}$$

□ Current control loop



$i_d \Rightarrow \text{flux}$

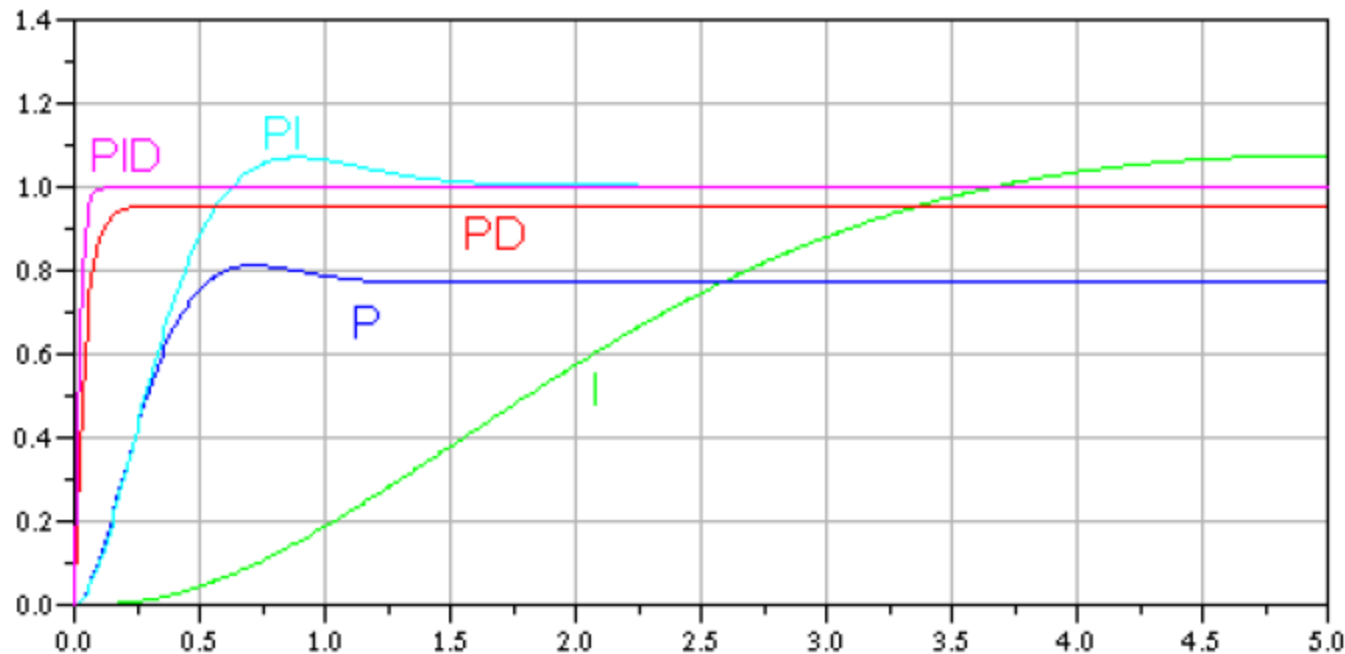
$i_q \Rightarrow \text{torque}$



In current loop, i_d controls the motor flux for extending speed region, and i_q controls motor torque for increasing and decreasing speed.

□ PID-Regulator Control

- Universal regulator for most of the control loops
- Very accurate and fast
- Stable control loop
- In the absence of knowledge of the underlying process, a PID controller is the best controller solution



Algorithm Function

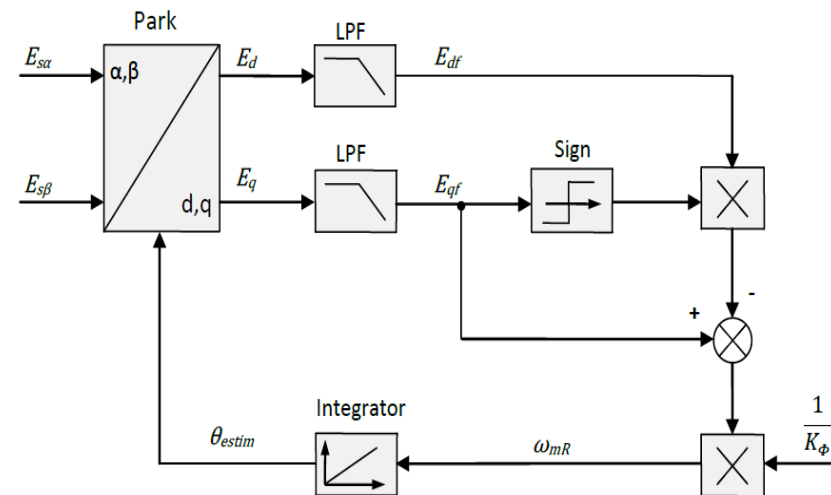
□ Position Estimate

➤ PLL

➤ SMO

➤ HFI

➤ DTC



$$\begin{cases} E_\alpha = V_\alpha - R_s I_\alpha - L_s \frac{dI_\alpha}{dt} \\ E_\beta = V_\beta - R_s I_\beta - L_s \frac{dI_\beta}{dt} \end{cases}$$

$$\begin{cases} E_d = E_\alpha \cos(\theta_{estim}) + E_\beta \sin(\theta_{estim}) \\ E_q = E_\beta \cos(\theta_{estim}) - E_\alpha \sin(\theta_{estim}) \end{cases}$$

$$\omega_{mR} = \frac{1}{K_\phi} (E_{qf} - \text{Sign}(E_{qf}) * E_{df})$$

$$\theta_{estim} = \int \omega_{mR} dt$$

Algorithm Function

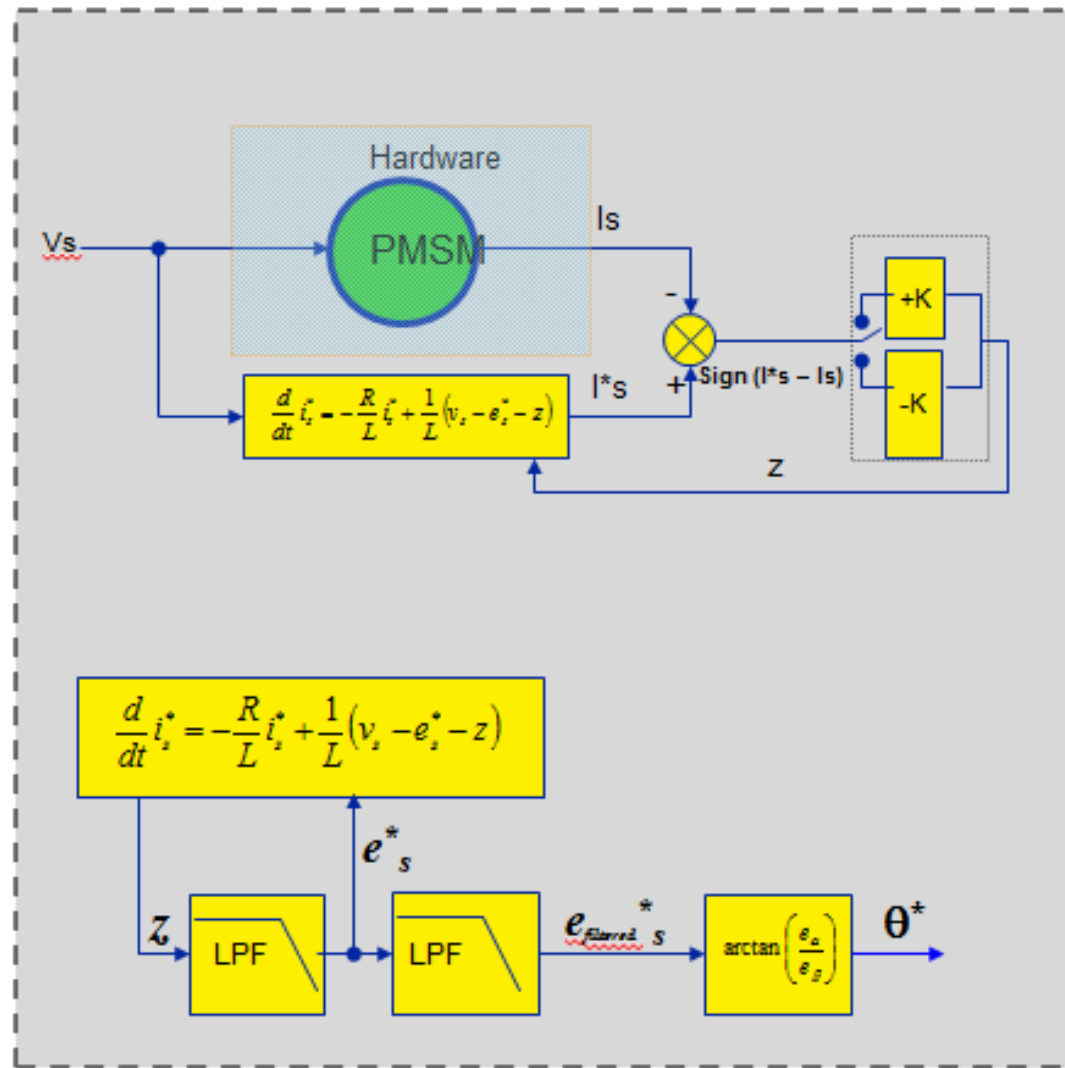
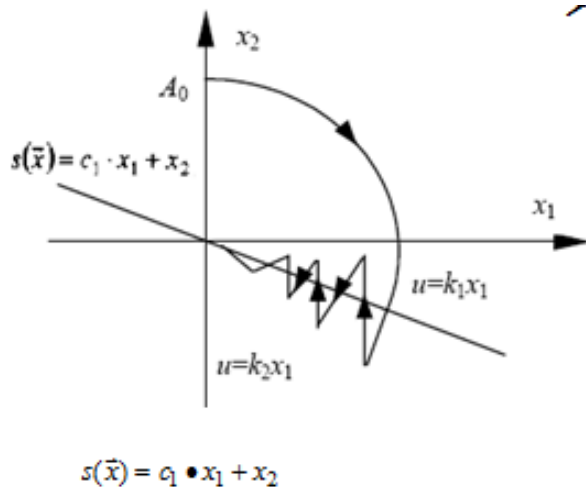
□ Position Estimate

➤ SMO

➤ PLL

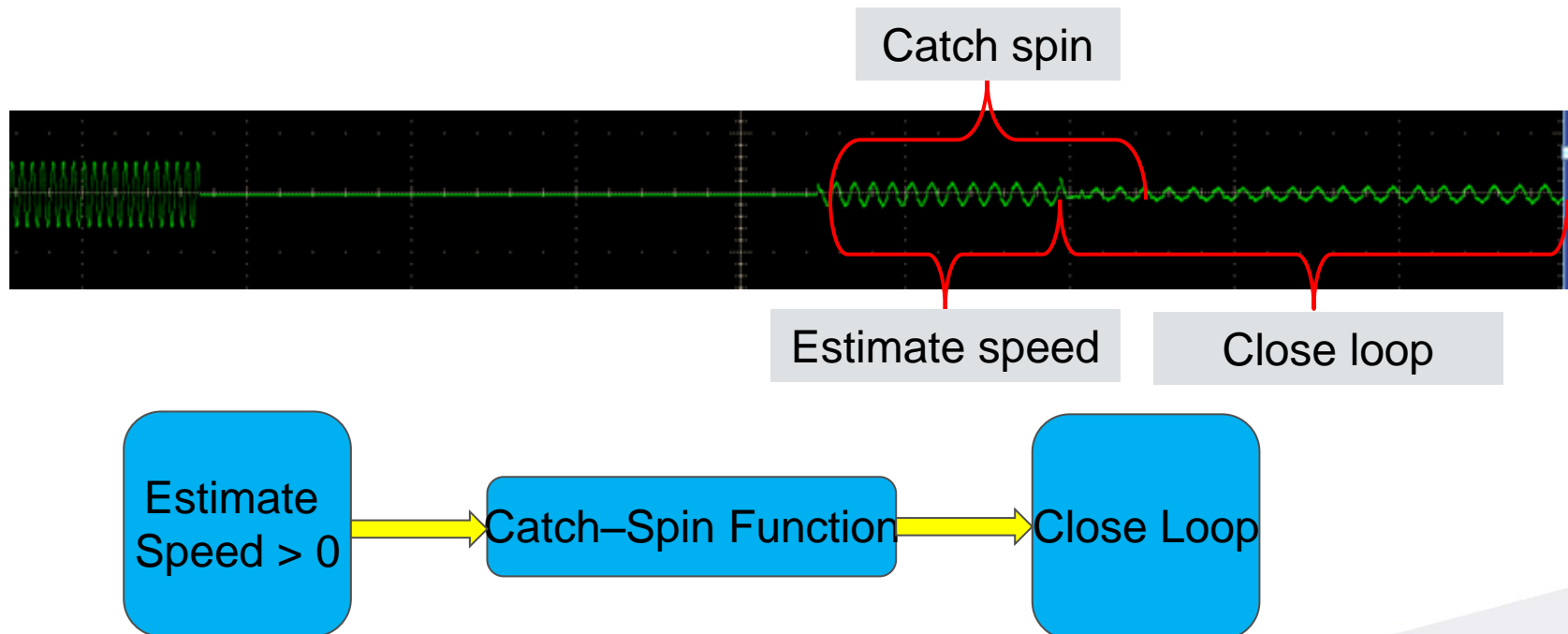
➤ HFI

➤ DTC



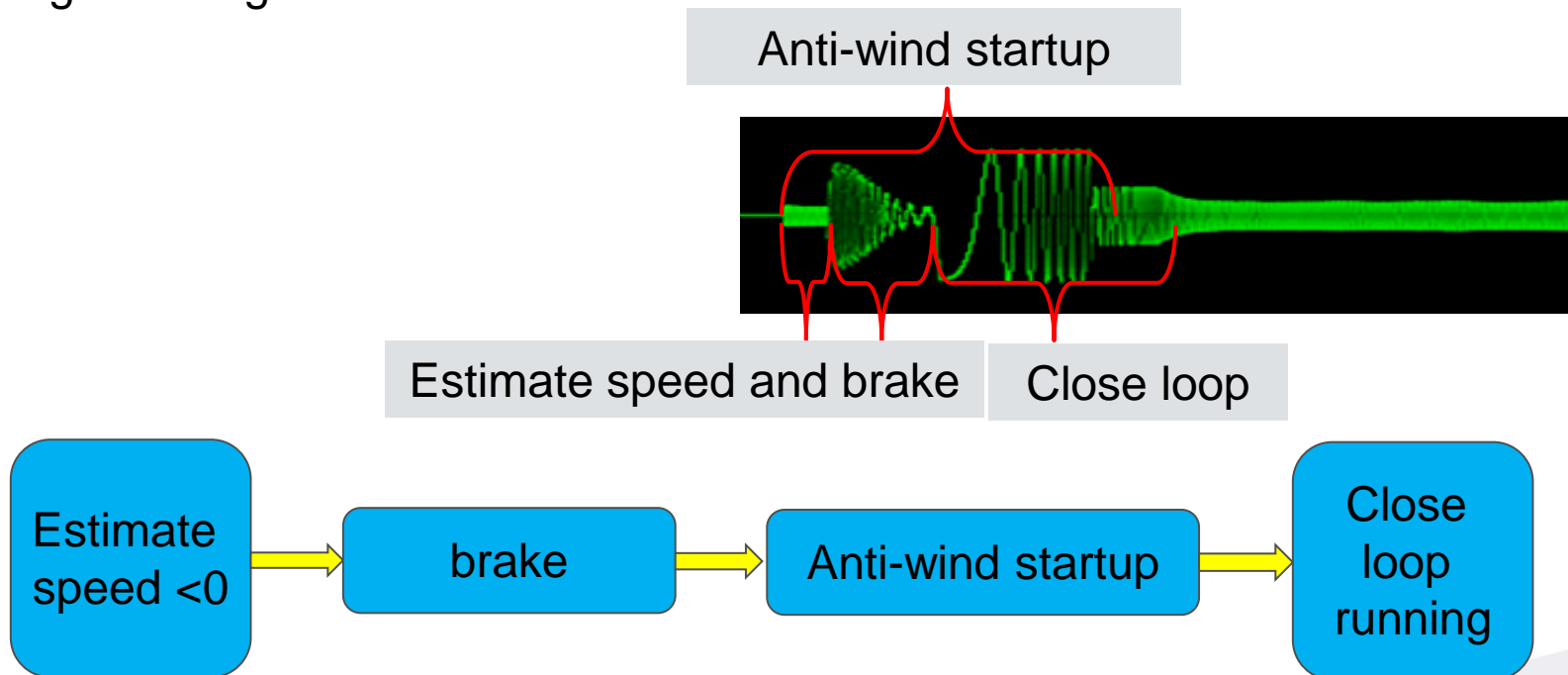
❑ Catch-Spin Function:

- From the rotor estimate speed, you can judge the start mode, If the speed is bigger than zero, use the catch-spin function. Otherwise, use other start mode.
- Algorithm figure is shown as below:



□ Anti-wind start:

- From the rotor speed detection, once the rotor reverse running is detected, Anti-wind start function will be started. Adjust the startup current and brake time based on the reverse speed. When the speed decreases to zero, the system enters the close-loop running stage.
- Algorithm figure is shown as below:

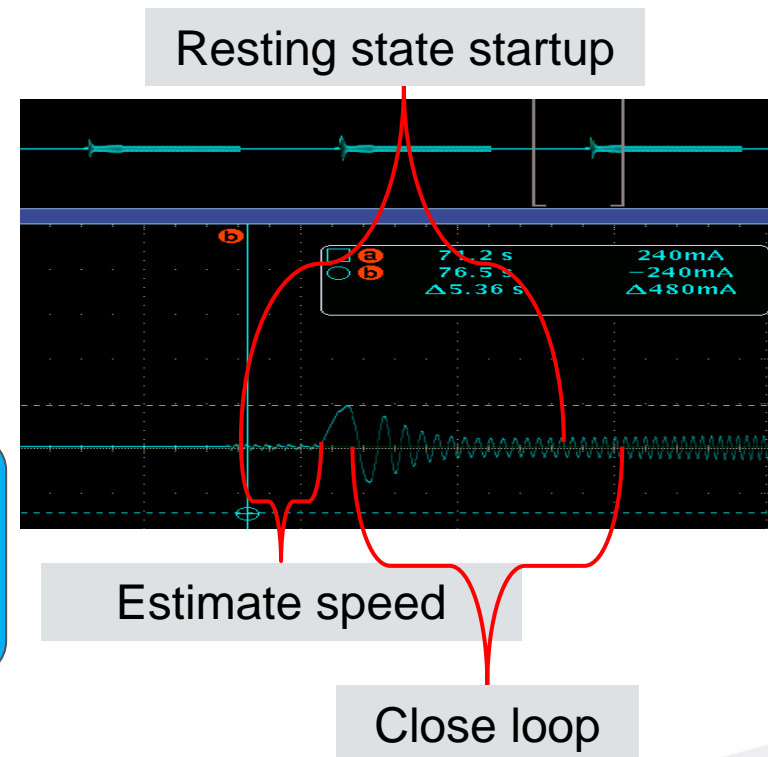


Algorithm Function

❑ Resting state start:

- From the rotor speed detection, If it is detected that the rotor speed equals to zero, the Resting State Startup function will be started. Adjust the startup current based on the target speed and load. Then, enter close-loop running directly.

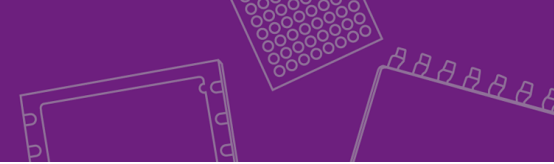
- Algorithm figure is shown as below:





Solution Performance Feature

Performance Comparison



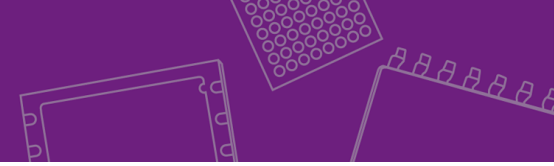
- ❑ Competitor's sensor-less DC fan starts up with orientation and big open-loop current, which has below disadvantages:
 - Orientation causes more vibration and longer startup time;
 - Open-loop needs bigger current;
 - The anti-wind performance is bad and the startup speed is lower than 500rpm;
 - Startup time is long;
 - Speed up and down will cause current fluctuation.
- ❑ Spansion DC fan solution using new startup algorithm can avoid disadvantages of other solutions and provide the following features:
 - Don't need orientation, no vibration;
 - Millisecond-level startup time;
 - 1000rpm anti-wind startup;
 - Startup current below 0.2A, anti-wind startup maximum current below 0.7A;
 - Maximum startup time below 2s;
 - Startup time and current can auto-adjust;
 - Speed up and down will not cause current fluctuation.

Performance Comparison



Function	Competitor solution	Spancion solution
Orientation	Need orientation startup, orientation time about 4S , current 0.7A , bigger vibration and long start time	Do not need orientation. Orientation time 0S , current 0A , startup no vibration.
Open-loop startup	Need open-loop startup, open-loop time about 0.4S , current about 0.85A	Do not need. Using pre-close-loop mode, time maximum value about 0.2S , maximum current about 0.2A
Anti-wind startup	Anti-wind startup is OK only under 300RPM . When the value is 300RPM--500RPM , the startup may fail. When the value is above 500RPM , no startup can succeed	All anti-wind startups are OK under 1000RPM
Startup time	startup time total 4.5S	startup time total 0.2S
Startup power loss	Startup power loss about: $(0.7A \cdot 0.7A \cdot 4S + 0.85A \cdot 0.85A \cdot 0.4S) \cdot R / 2$ $= (1.96 + 0.289) / 2 = \mathbf{1.1245J}$	Startup power loss about: $(0.2A \cdot 0.2A \cdot 0.2S) \cdot R / 2 = \mathbf{0.004J}$ (only other solution power 's 0.356%)
Startup type	Startup without self-adaption; current and time are constant values.	Startup using self-adaption method, current and time will be controlled to the minimum.

Solution Features



- ☐ Using Spansion 32bit ARM Cortex-M3/FM0+ chip: MB9AF132K, frequency 20MHz/SE1A1, frequency 40MHz
- ☐ MOSFET or IPM power module can be chosen
- ☐ VF/VF_Diagnosis /Speed/Torque control mode
- ☐ No-orientation and open loop startup
- ☐ The online self-adaptation function of 5KHz-30KHz carrier frequency can meet the requirements of reducing noise
- ☐ Support single shunt and dual shunt algorithm
- ☐ Anti-wind startup can reach 1000rpm
- ☐ Unstop-running function
- ☐ Support PWM mode brake function
- ☐ Catch-spin function
- ☐ Support flux-decrease protection
- ☐ Perfect protection function
- ☐ Meet the national energy consumption requirements of energy efficiency



SpanSion Solution Development

Background Introduction

Memory

High Quality
Flash
100k erase cycles
20 years
retention

Fastest
Flash Memory
among
ARM Cortex M0+
/M3/M4
families

Wide supply
voltage range
2.7V..5.5V
1.65V..3.6V

Core

High
Performance
up to 144MHz
operation
frequency

Sophisticated
Motor Control
Timer

Independent
12-bit ADCs

Peripherals

Advanced
Connectivity
USB host+function
CAN
Ethernet

Many functional
safety features

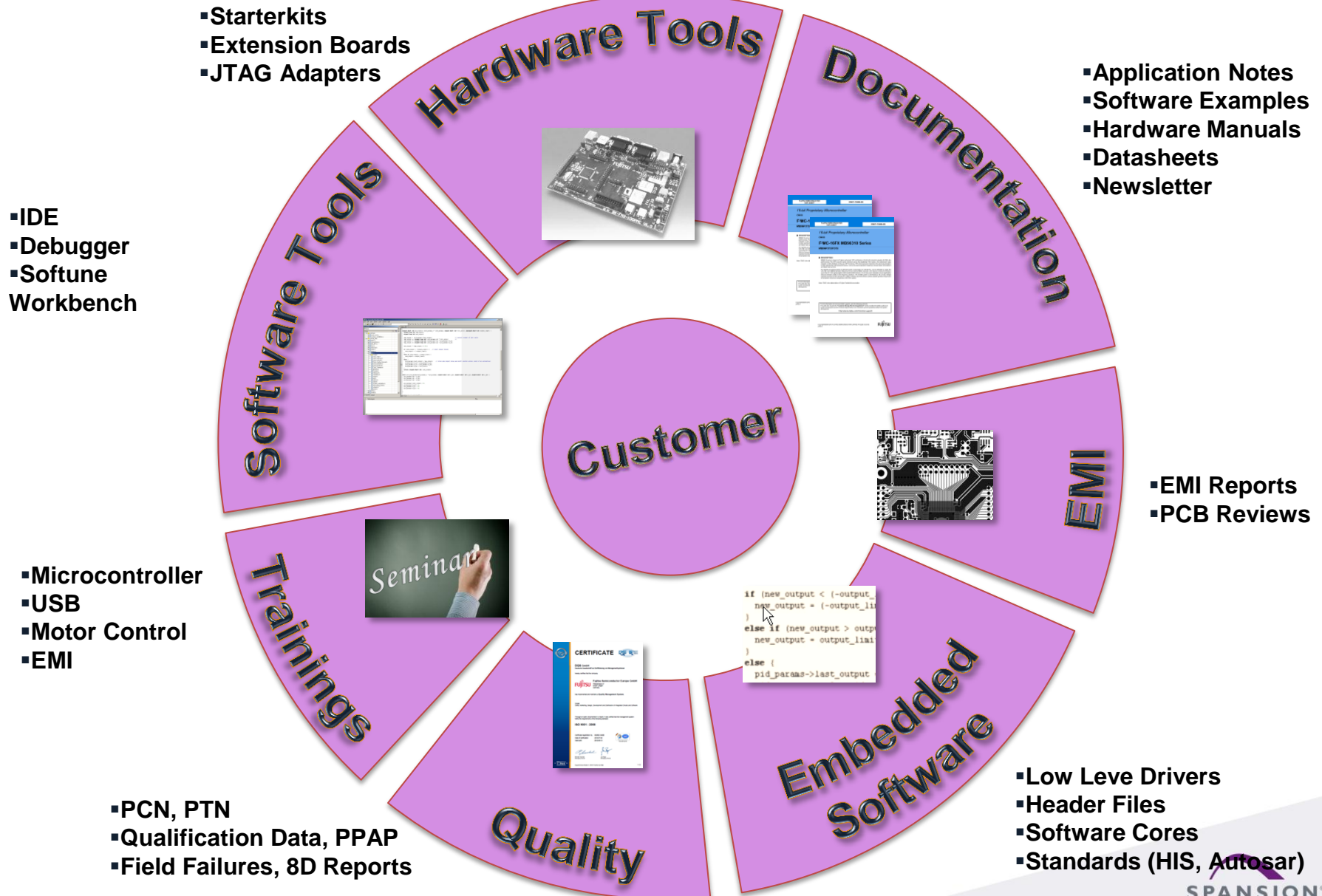
Long term
Availability
10years +

Support

Global
Excellent
Technical
Support



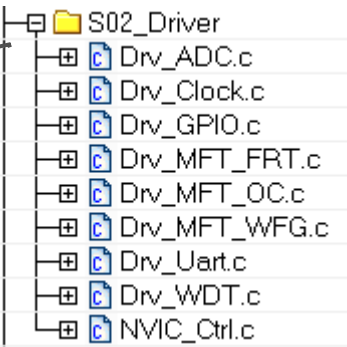
Spancion Resources



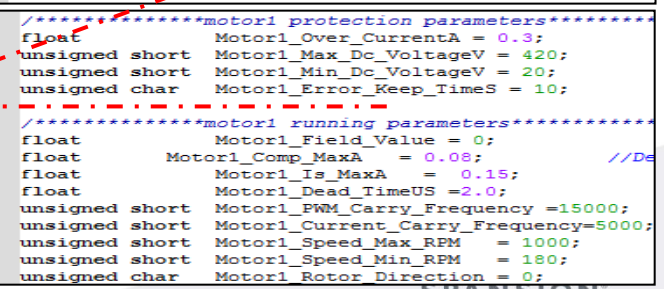
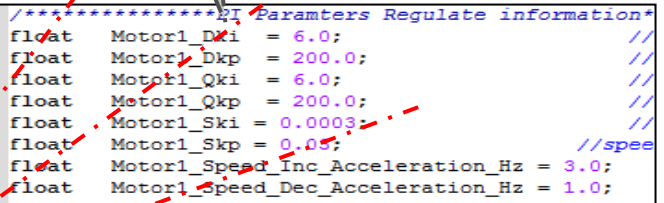
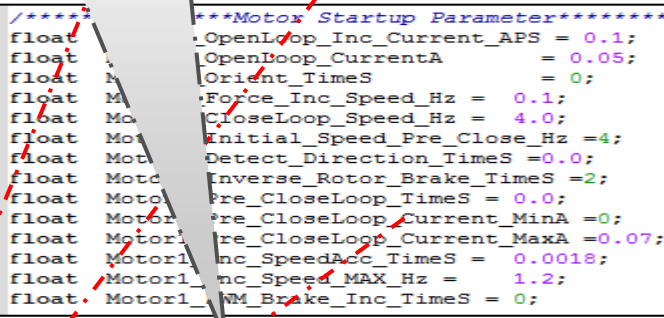
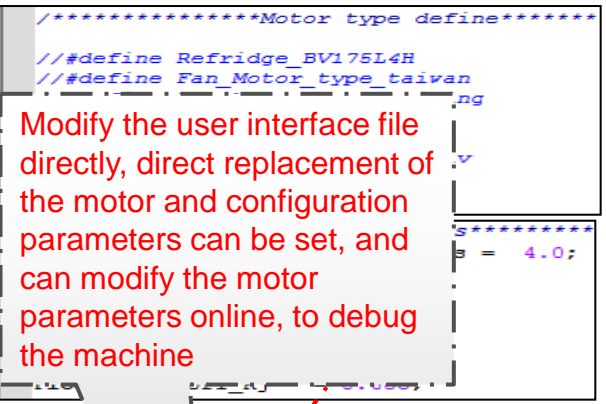
Solution Development

IAR Embedded Workbench IDE

Completely open chip driver code, to achieve quickly switch and change of the chip



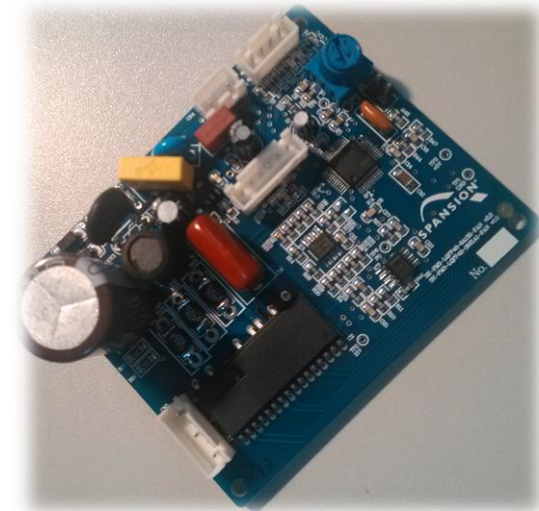
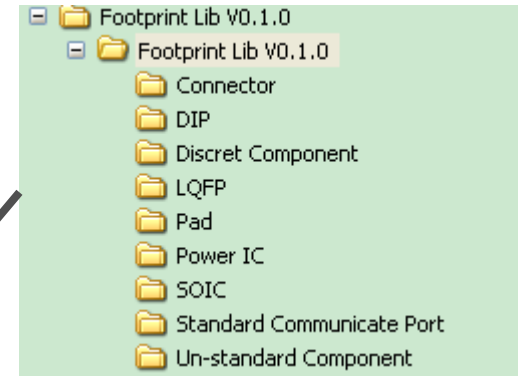
Modify the user interface file directly, direct replacement of the motor and configuration parameters can be set, and can modify the motor parameters online, to debug the machine



Provide complete new function sample project fast
Project of custom and replacement of the chip

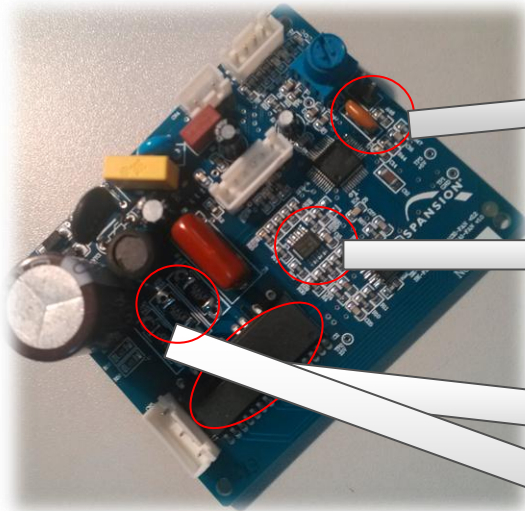
- ❑ Rich hardware reference standard circuit
- ❑ Current sampling amplifier circuit reference
- ❑ Different chip pin resource allocation model
- ❑ The hardware circuit reference over-current protection standards
- ❑ Providing rich component encapsulation library

❑ Reference sample



!!! Lower the development difficulty and reduce the risk; provide full set of hardware development platform to quicken the development.

❑ Low Hardware Cost



➤ *Support inner CR*

➤ *Support no Amplifier operations*

➤ *Support isolation IGBT*

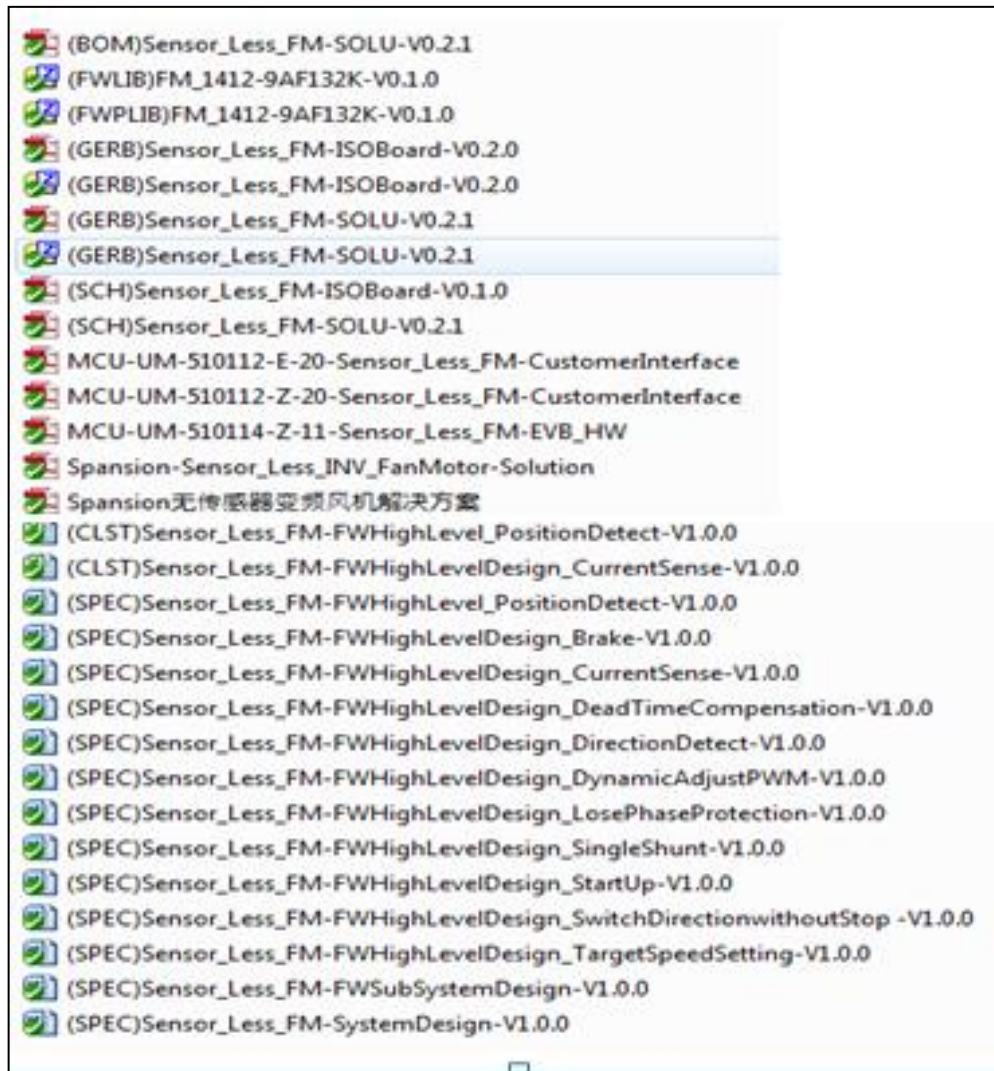
➤ *Support single shunt function*

!!! Reducing hardware cost and solution components to increase the solution advantage.

Solution Resources

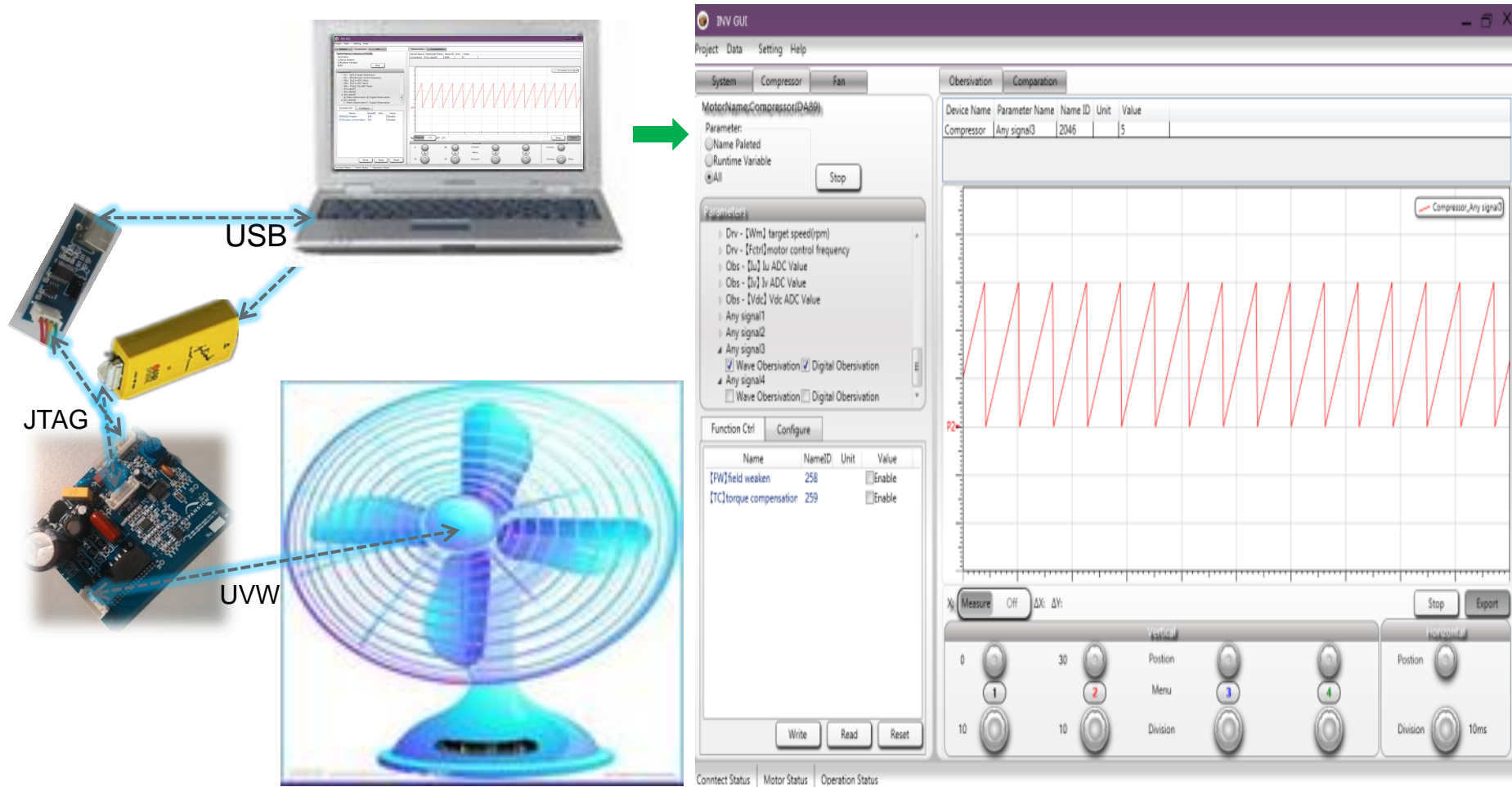
□ Resources include:

- Chip hardware user manual
- Hardware user manual
- Software debugger manual
- Sensor-less DC fan motor SPEC
- Development user manual
- Customer interface manual
- System designed SPEC
- Subsystem designed SPEC
- System test SPEC
- Protection test and mode SPEC
- Test report
- Firmware materials



Solution Development

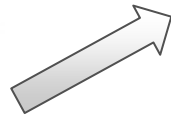
□ GUI debugger





Supported Products

Supported Products



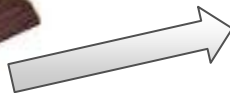
❑ Special feature

- Standard interface
- Fast increasing speed in dedusting
- Anti - wind startup



❑ Special feature

- No-orientation stage
- No start swing
- Catch spin function



❑ Special feature

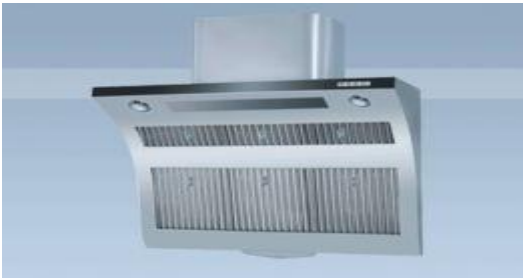
- Low speed running
- Low vibration

Supported Products



❑ Special feature

- High speed running
- Light current



❑ Special feature

- Torque control
- Fast startup



❑ Special feature

- Low voltage running

Supported Products

❑ Other product



Pump



Dishwasher



Hair dryer



Electric drill



www.spansion.com

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